

PROCESS FOR THE CONTROLLED OXIDATION OF A STRIP BEFORE  
CONTINUOUS GALVANIZING, AND GALVANIZING LINE

5 The invention relates to a process for the continuous hot-dip galvanizing of a steel strip, the steel containing oxidizable addition elements in a proportion allowing the mechanical properties of the steel to be improved.

10 The improvement in mechanical properties of the steel goes either towards increasing the mechanical strength, for example for the purpose of reducing the thickness and therefore the weight of steel, or towards increasing the drawability, or else towards both these  
15 criteria. This has resulted in the development of multiphase grades of steel, for example of the DP (dual phase) and TRIP (transformation-induced plasticity) type.

20 These very high-strength multiphase grades are generally obtained by the addition of hardening elements, such as Si, Mn, Cr, Mo, etc.

Hot-dip galvanizing furnaces according to the prior art  
25 usually comprise several sections equipped to carry out various steps of the heat treatment, these being, in general: heating, soaking and cooling. The heat treatment furnace is conditioned using an inert or reducing atmosphere, generally consisting of a  
30 nitrogen/hydrogen mixture intended to reduce the iron oxides present on the surface of steel sheets before they are galvanized.

It has been observed that, in the case of multiphase  
35 steels, elements such as Si, Mn, Cr, Mo, etc. present in the steel, which are more oxidizable than iron, preferentially combine with the oxygen atoms present in the furnace to form oxides on the surface of the strip.

The very high oxidation potential of these components even results in migration of their atoms towards the surface of the strip so that they can be oxidized by the oxygen present in the furnace.

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The result is the formation of a thin oxide layer on the surface of the strip. These oxides are stable and are not reduced during its passage through the various zones of the furnace - they are therefore still on the surface of the strip when it is dipped into the zinc bath and obstruct the adhesion of the zinc during the galvanizing operation. Reducing the dew point of the atmosphere inside the furnace to limits compatible with the current prior art has not eliminated this phenomenon, and the presence on the surface of a galvanized strip of defects caused by the local presence of these oxides is still observed.

20 It follows that, at the present time, the steel strip hotdip galvanizing process does not allow correct galvanizing of multiphase steel grades having a content of oxidizable elements, such as Si, Cr, Mn, Mo, etc., that is sufficient to improve the mechanical properties of the steel.

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The object of the proposed invention is to provide a continuous hot-dip galvanizing device and process that allow correct treatment of a strip containing oxidizable addition elements whose content is sufficient to improve the mechanical properties of the steel.

35 The invention relates to a line for the continuous hot-dip galvanizing of a steel strip containing oxidizable addition elements in a proportion allowing the mechanical properties of the steel to be improved, in which line the strip passes through a galvanizing furnace in a reducing atmosphere before being dipped into a galvanizing bath, this line being characterized

in that it comprises, upstream of the galvanizing furnace, a means for heating the strip to a suitable temperature followed by a zone for exposing the strip to an oxidizing atmosphere, the oxygen content of which  
5 is such that, owing to the temperature of the strip and the duration of the treatment, the oxidizable addition elements in the steel strip are oxidized at the surface and immediately beneath the surface of the strip before they can migrate to the said surface, in order to form  
10 thereat a layer of oxides capable of causing galvanizing defects. The iron oxides produced during this operation will be reduced while the strip is passing through the furnace.

15 Advantageously, the strip is heated to a temperature of between 150°C and 400°C, preferably between approximately 150°C and 300°C, for the oxidation treatment. For a given grade of steel, the oxidation of its surface will be controlled, for a given oxidizing  
20 atmosphere, by the choice of a pair of parameters, namely the temperature and the residence time of the strip in the oxidizing atmosphere.

This temperature/residence time pair will be  
25 continuously monitored and will take the operating speed of the line into account, in particular the instantaneous run speed of the strip. The strip oxidation treatment may be controlled by regulating the heating power upstream of the furnace (thus varying the  
30 temperature of the strip) or by varying the distance between the heating element located upstream of the furnace and the inlet of the furnace (which varies the oxidation time).

35 The oxidizing atmosphere in which the controlled oxidation operation is carried out on the surface of the strip may be the ambient air or any other confined atmosphere in a chamber which is installed upstream of the furnace and the oxygen content of which will be

controlled.

The invention consists, apart from the arrangements mentioned above, of a certain number of other  
5 arrangements which will be more explicitly mentioned below with regard to illustrative examples described in detail with reference to the appended drawings, but which are in no way limiting:

- Figure 1 is a diagram of a continuous hot-dip  
10 galvanizing line for implementing the process of the invention;

- Figure 2 is a graph showing the variation in temperature of a point on the strip, plotted on the y-axis as a function of the position of the point on the  
15 line plotted on the x-axis;

- Figure 3 is a diagram of an alternative embodiment of the galvanizing line; and

- Figures 4 to 6 are other alternative embodiments.

20 In the case of Figures 1 to 4, the strip is moving from the left to the right.

Shown schematically in Figure 1 of the drawings is a line for the continuous hot-dip galvanizing of a steel  
25 strip 1 in a molten-zinc galvanizing bath 2.

The line includes a galvanizing furnace 3 according to the prior art, for treating the strip 1 before it is dipped into the bath 2. The furnace comprises several  
30 sections equipped for carrying out in succession the various steps of the heat treatment, which are in general heating, soaking and then cooling down to a temperature suitable for depositing the zinc on the surface of the strip. The atmosphere in the furnace 3  
35 is reducing, produced by a conventional nitrogen/hydrogen gas mixture with a dew point maintained as low as possible.

The steel strip 1 contains oxidizable addition

elements, such as Si, Cr, Mn and Mo, in proportions sufficient to improve its mechanical properties. Hitherto, this type of galvanizing line has not allowed a steel containing such oxidizable elements in such proportions to be correctly galvanized in a continuous hot-dip operation since, as explained above, during the high-temperature heating and soaking treatment, a very thin layer of oxides of these addition elements forms on the surface and remains, right in the molten zinc, thereby causing defects in the coating.

According to the invention, the strip 1 is subjected, upstream of the furnace 3, in a zone 8 to an oxidation treatment under atmosphere/temperature and residence time conditions such that the oxidizable addition elements, especially Si, Cr, Mn or Mo, are oxidized beneath the surface of the strip before they can migrate to this surface in order to form an oxide layer capable of causing galvanizing defects.

Under these conditions, during the treatment in the furnace 3, the oxides of the addition elements remain trapped within the material and there is no longer any migration of addition elements to the surface of the strip capable of enriching the oxide layer up to the point of causing of galvanizing defects.

Iron oxides are formed on the surface of the strip during treatment in the zone 8 and going from the zone 8 as far as the inlet of the furnace. These iron oxides are reduced within the chamber of the furnace 3 in such a way that the strip 1, when it enters the molten zinc bath 2, has a surface with a layer of reduced oxides of the addition elements, which allows correct galvanizing to occur.

The zone 8 includes a heating means for raising the strip 1 to the desired temperature, typically between 150°C and 400°C. A control means 7 consisting of a

computer is provided in order to adjust the heating of the strip on the basis of sensors, such as a strip speed sensor 4, a strip surface temperature sensor 5 and a strip surface emissivity sensor 6.

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The oxidation rate is controlled, for a given oxidizing atmosphere, as a result of controlling the final temperature of the strip 1 as it leaves the heating means 8 and the residence time of the strip 1 in the zone 8 and between the zone 8 and the inlet of the furnace 3. The combination of these parameters is optimized depending on the grade of steel to be treated, the speed of the line and the thickness and width of the strip.

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The heating means 8 is chosen to have a low thermal inertia and a high reactivity so as to maintain control of the surface oxidation of the strip during transient phases brought about by changes in the speed of the line or changes in geometry of the strip 1. This heating means 8 may consist of a gas furnace, of the naked flame or indirect heating type, but preferably his heating means will consist of an electromagnetic induction furnace. The induction furnace has at least one induction coil that can be moved up to or away from the galvanizing furnace in order to vary the heating rate produced.

The oxidation treatment of the strip 1 in the zone 8 and between the zone 8 and the inlet of the furnace 3 will preferably be carried out in air. The oxidation of the strip will then be controlled by controlling two parameters, namely the temperature of the strip leaving the zone 8 and the residence time of the strip in air between its entry into the zone 8 and its entry into the furnace 3. The temperature will have to be increased when the speed of the line increases, so as to compensate for the shorter residence time of the strip at high temperature in the air.

Figure 2 shows the temperature variation of a point on the strip 1 plotted on the y-axis as a function of the position of this point on the line plotted on the x-axis. Upstream of the heating means 8, the temperature of the strip is low, for example below 100°C, and corresponds to the segment 9. As the strip 1 passes through the heating means 8, its temperature increases, for example as per the inclined segment 10. The temperature of the strip 1, from the point where it leaves the heating means 8 up to the point where it enters the furnace 3 remains approximately constant, as shown schematically by the segment 11 - the oxidation treatment continues during this phase. Within the chamber of the furnace 3, the strip 1 will continue to be heated in a cycle tailored to its metallurgy and shown symbolically by 12.

The oxidation of the strip may be controlled by varying one or more of the parameters presented in Figure 2. It is possible to vary the temperature of the strip by varying the mean slope of the segment 10, in order to obtain a variable temperature hold level of the segment 11. It is also possible to vary the duration of the temperature hold 11 or to modify the effectiveness of the strip oxidation during the temperature hold 11, for example by varying the concentration of oxygen in the oxidizing atmosphere to which the strip is exposed during this temperature hold.

Figure 3 shows a variation of Figure 1 in which the heating zone 8 is connected in a sealed manner to the inlet of the furnace 3 by the chamber 13. It will be understood that, within the chamber 13, it is possible to control the oxygen concentration so as to tailor the oxidation of the strip to the specific type of steel, to the speed of the strip and to any other parameter necessary for controlling the oxidation rate of the strip. The oxygen content of the chamber 13 and the

means for sealing this chamber with respect to the outside or with respect to the chamber of the furnace 3 will be controlled using the means of the prior art.

5 The duration of the oxidation treatment may be advantageously controlled, according to the operating parameters of the line, by modifying the length of strip 1 between the outlet of the heating means 8 and the inlet of the furnace 3. This length variation may  
10 be accomplished in various ways.

One possible way consists in moving the heating means 8 along the direction of the strip 1, as illustrated schematically in Figure 4 by the dashed arrow 14. For a  
15 given strip speed, when the heating means 8 is brought closer to the furnace 3, the treatment type decreases, whereas when the heating means 8 is moved further away from the furnace the treatment time increases.

20 A second possible way is illustrated by Figure 5. The heating means 8 are stationary and, between the heating means 8 and the furnace 3, the strip 1 passes over a fixed roll 15 and over a moving roll 16, which can be moved parallel to the direction of the strip as  
25 illustrated schematically by the arrow 17. When the moving roll 16 is moved to the right, the length of strip between the heating means 8 and the furnace 3 increases, thereby increasing the duration of the oxidation treatment. Conversely, when the moving roll  
30 16 is moved to the left in Figure 5, the length of strip decreases, thereby reducing the treatment time. This arrangement with a moving roll 16 and two horizontal strip strands may be repeated several times with several rolls and several strands of variable  
35 length, so as to increase the length of strip between 8 and 3 and to increase the possible variation in this length.

Figure 6 shows an alternative embodiment of Figure 5,



in which the heating means 8 are stationary and the strip 1 passes over two fixed rolls 20 and 21 and over one moving roll 19, which can be moved perpendicular to the main direction of the strip as illustrated schematically by the arrow 18. When the moving roll 19 is moved upwards, the length of strip between the heating means 8 and the furnace 3 increases, thereby increasing the oxidation treatment time. Conversely, when the moving roll 19 is moved downwards in Figure 6, the length of strip decreases, thereby reducing the treatment time. This arrangement with a roll 19 and two vertical strands may be repeated several times so as to increase the length of strip between 8 and 3 and to increase the possible variation in this length.

It will be understood that all the combinations of fixed rolls and moving rolls allowing the length of strip between the heating means 8 and the inlet of the furnace 3 to be varied make it possible to vary the strip oxidation time and may be implemented within the context of this invention.

It is also possible to place the rolls 15 and 17 of Figure 5 or the rolls 19, 20 and 21 of Figure 6 in a chamber such as 13, in which the oxygen concentration may be controlled and adjusted to the treatment to be obtained.

It will also be understood that it is possible to combine controlling the temperature of the strip as it leaves the heating means 8 with controlling the duration of oxidation according to the characteristics of the material and to the intended objectives. This control of the temperature and of the treatment time, and also the operation of the corresponding actuators, is performed by the computer 7 according to the product data input by the operator and also the measurements carried out by the sensors, such as 4, 5, and 6 for example.

Thanks to the use of these devices, the strip 1 enters the molten zinc bath 2 with a surface on which the formation of oxides has been limited, including in the case of the oxides of the addition elements, in such a way that the adhesion of the zinc to this surface can be optimal.

The galvanizing line according to the invention constitutes a flexible production tool allowing economic galvanizing of various grades of steel, irrespective of the nature of their additives, without any defect in the zinc coating on their surface. The control means 7 and the heating means 8, owing to the speed with which they can be adapted, allow the oxidation control process to be adapted to products of any dimensions and to any variation in the speed of the production line.

It may also be noted that the devices needed to implement the method of controlling the oxidation of a strip containing additives such as Si, Cr, Mn, Mo, etc. may be easily added to an existing plant in order to extend its production range or, in a plant in which they are installed, they can be readily neutralized for the production of grades of steel not containing these additives.